CHAPTER 2. PART 27
AIRWORTHINESS STANDARDS
NORMAL CATEGORY ROTORCRAFT

SUBPART C - STRENGTH REQUIREMENTS

STRENGTH REQUIREMENTS - GENERAL

AC 27.301. § 27.301 LOADS.

a. Explanation.

(1) The rule is a general statement concerning limit and ultimate loads and the application of these loads to the rotorcraft.

(2) Ultimate loads are limit loads multiplied by the prescribed factors of safety.

(3) The specified loads are specified to be distributed appropriately or conservatively and significant changes in distribution of the loads, as a result of deflection, are specified to be taken into account.

b. Procedures. The design criteria report and/or design loads report should contain data that comply with the rule.

AC 27.303. § 27.303 FACTOR OF SAFETY.

a. Explanation.

(1) Unless otherwise provided by Part 27, a factor of safety of 1.5 is required and is applied as stated in the rule. This safety margin will ensure that the design strength of the rotorcraft is greater than the design loads contained in Part 27.

(2) Other rules, §§ 27.561(b)(3) and 27.787(c), specify use of defined ultimate inertial forces for protection of occupants.

b. Procedures.

(1) The design criteria report and/or design loads report should contain data that include the appropriate factor of safety.

(2) The factor of safety multiplies the limit external and inertial loads. The rule does allow the application of this factor to the resulting “limit internal” stresses if it is more conservative.

AC 27.305. <u>§ 27.305 STRENGTH AND DEFORMATION</u>.

a. <u>Explanation</u>.

(1) This general rule defines, in relative terms, allowable deformation for limit and ultimate loads.

(2) The structure is required to be able to support, in a static test, ultimate loads for 3 seconds without failure, or dynamic tests simulating actual load application may be used.

(3) Section 27.307 concerns proof of the structure and requires certain specified tests. This rule also allows substantiation by structural analysis. See paragraph AC 27.307.

b. <u>Procedures</u>. Any test results, static or dynamic, should satisfy the limitations or acceptance criteria contained in the rule.

(1) Any test proposals submitted for approval that are used to demonstrate compliance with sections of Part 27 should contain the criteria stated in the rule.

(2) Any test results reports shall contain data and information showing the test results comply with the standard.

AC 27.307. <u>§ 27.307 (Amendment 27-3) PROOF OF STRUCTURE</u>.

a. <u>Explanation</u>.

(1) The rule requires compliance with the strength and deformation requirements for each critical loading condition. Certain tests must be conducted as specified. Additional tests for new or unusual design features may be required as noted in § 27.307(b)(6).

(2) Structural analysis rather than load tests may be used only if the structure conforms to those for which experience has shown the structural analysis method to be reliable.

b. <u>Procedures.</u>

(1) The design criteria and/or design loads report should contain typical or representative loading conditions from which the critical loading conditions will be selected for analytical substantiation in structural (static and fatigue) reports, dynamics (vibration and stability) reports, and in fatigue, static, dynamic, or operational test reports.

(2) Whenever tests are used or required, a test proposal or plan should be approved prior to the tests. The test article should have received conformity inspections and should have been accepted by the FAA/AUTHORITY for the test. Test fixtures and instrumentation should also be acceptable to the FAA/AUTHORITY (using DERs as appropriate) prior to the start of the test. The quality control office of the applicant or other qualified personnel may be authorized to conduct inspections of the test fixtures and instrumentation rather than the FAA/AUTHORITY or DER performing this task. The test proposal may be used to define and to authorize the means to accomplish inspection of the test fixtures and instrumentation. Unnecessary drawings such as test fixture details or layering of approvals are not intended or envisaged by this policy. Drawings, sketches, or photographs have been used by the FAA/AUTHORITY to control and to ensure correct location, direction, and magnitude of loads and other critical test parameters.

(3) Structural analysis has been accepted for rotorcraft in place of static tests. Generally, the rotorcraft airframe should have natural frequencies remote to predominant rotor excitation sources, including higher harmonics, to avoid undesirable and possibly excessive vibration and potentially high operating stress levels due to this vibration. During the flight load measurement program conducted under § 27.571, critical loaded areas or critical joints may be instrumented with strain gages or other stress strain measuring devices. This actual flight data should be compared to the analytical data to verify accuracy.

(4) Paragraph (b) of the rule specifies certain tests. Test proposals should be approved prior to conducting official FAA/AUTHORITY tests. Other paragraphs in this advisory circular pertain to those tests.

AC 27.307A. § 27.307 (Amendment 27-26) PROOF OF STRUCTURE.

a. Explanation. Amendment 27-26 adds the requirement to account for the environment to which the structure will be exposed in operation. This change is intended to codify recent FAA/AUTHORITY and industry practices for the consideration of environmental effects in showing “proof of structure.”

b. Procedures. All of the policy materials pertaining to this section remains in effect with the following additions:

(1) For either tests or an analysis, environmental effects are now explicitly required. Consideration of loss of strength and stiffness of metals with elevated temperatures and loss of strength and stiffness of composite materials from exposure to heat, moisture, or other operational environments is now required and should be documented in analyses and test reports.

(2) MIL-HDBK-5F; AC 20-107B; or MIL-HDBK-17, Vol. I, Rev 1E; Vol. II, Rev. D; Vol. III, Rev E (or later versions) are acceptable sources of data and procedures

to show compliance with environmental effects of metallic and composite materials, respectively.

AC 27.309. <u>§ 27.309 DESIGN LIMITATIONS</u>.

a. <u>Explanation</u>.

(1) The rule requires an orderly selection and presentation of the basic structural design limitations of the rotorcraft. The applicant is required to establish these structural limitations to facilitate design of the rotorcraft.

(2) Refer to the rule for the specific requirements.

b. <u>Procedures</u>.

(1) The design criteria and/or design load report should contain the design limits specified.

(2) These items are structural design limits. Other requirements may result in narrowing the ranges of type design limits or in reducing limits. It is not necessary to revise structural design criteria limits to agree with more conservative operational limits established during the certification program. The operational limits may be subsequently expanded by additional flight tests to agree with design limits.

SUBPART C - STRENGTH REQUIREMENTS

FLIGHT LOADS

AC 27.321 § 27.321 (Amendment 27-11) FLIGHT LOADS--GENERAL.

a. Explanation.

(1) The rule specifies the way the loads will be applied to the rotorcraft. It requires load analysis from minimum to maximum design weight. Any practical distribution of disposable loads must be included in the analysis.

(2) Paragraph (a) of the rule states: "The flight load factor must be assumed to act normal to the longitudinal axis of the rotorcraft, and to be equal in magnitude and opposite in direction to the rotorcraft inertia load factor at the center of gravity."

b. Procedures.

(1) Derivation of the flight loads is required by and specified in §§ 27.337 through 27.351. This rule requires flight load determination from minimum to maximum weight and for disposable loads.

(2) The application of the design loads derived from the flight load factor will be as specified. The flight loads analysis data must comply with the rule.

AC 27.337 § 27.337 (Amendment 27-26) LIMIT MANEUVERING LOAD FACTOR.

a. Explanation. The rotorcraft must be designed and substantiated to load factors as specified to provide a minimum level of structural integrity of the rotorcraft airframe and rotors.

(1) A range of design positive load factors from +3.5 to +2.0 may be used.

(2) A range of design negative load factors from -1.0 to -0.5 may be used.

(3) Load factors inside the range of +3.5 to -1.0 may be used provided the probability of exceeding the design load factors is shown by analysis and flight tests to be extremely remote and the selected load factors are appropriate to each weight condition between design maximum and minimum weight.

(4) Load factors exceeding these "minimums" may be used.

b. Procedures.

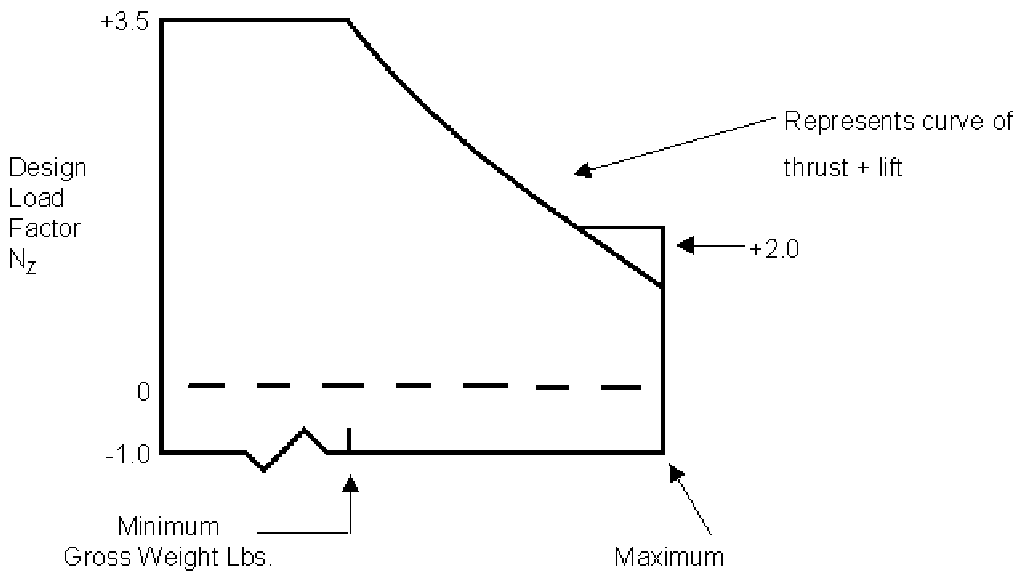
(1) The applicant may elect to substantiate the rotorcraft for a design maneuvering load factor less than +3.5 and more than -1.0. Whenever this option is used, an analytical study and flight demonstration are required.

(i) The maximum positive design load factor of +3.5 is generally at a weight below maximum gross weight. The maximum thrust capability of the main rotor, combined with incremental lift of wings or sponsons, if installed, results in a maximum design positive load factor. An example of a load factor-gross weight curve is shown in figure AC 27.337-1. Note the minimum positive design load factor is +2.0 even though the required analysis and flight demonstration may prove the rotorcraft is not capable of achieving this load factor. This curve also illustrates compliance with § 27.321(b)(1) since the design load factor varies with gross weight.

(ii) The largest negative design load factor is -1.0; however, several current rotorcraft designs are not capable of achieving a negative load factor. Therefore, -0.5 has been an acceptable structural design negative load factor for certain rotorcraft designs.

(2) Whenever the applicant analytically substantiates the lower load factors allowed by § 27.337(b), the flight demonstration required by § 27.337(b) must be conducted. The flight test personnel should determine that the demonstration shows the probability of exceeding the selected design load factors (those factors less than +3.5 and more than -1.0) is extremely remote. (See Order 8110.4, paragraph 166c(2)(c)).

(3) A numerical value has not been assigned to “extremely remote” in this standard.



LOAD FACTOR GROSS WEIGHT CURVE

FIGURE 27.337-1

AC 27.339 § 27.339 (Amendment 27-11) RESULTANT LIMIT MANEUVERING LOADS.

a. Explanation. The rule specifies or defines the application of rotor and lift surface loads to the rotorcraft.

(1) The design maneuvering load factors required by § 27.337 will result in or be derived from rotor thrust or lift and from auxiliary surface lift.

(2) Sections 27.321, 27.337, and 27.341 all complement one another and result in the derivation of design flight loads that will be imposed to ensure structural integrity of the rotorcraft.

(3) The following assumptions and conditions are specified in the rule.

(i) The rule requires application of appropriate loads at each rotor hub and auxiliary lifting surface.

(ii) Power-on and power-off flight with maximum design rotor tip speed ratio and specific conditions that must be considered.

(iii) Rotor tip speed ratio, defined in the rule, has been carried forward from the initial rotorcraft certification rules issued in 1946. The rotor tip speed ratio is a basic parameter used in calculating rotor aerodynamic forces.

b. Procedures.

(1) The rule specifies an acceptable assumption concerning application of the rotorcraft maneuvering loads.

(2) The rotor tip speed ratio is a parameter found in textbooks and other books such as NACA Report No. 716. The equation in the rule contains angle "a." Report No. 716 also defines angle "a" as the angle of attack of the rotor disk. This definition is more easily understood than the definition contained in the rule.

(3) The rotorcraft design loads are derived as prescribed by §§ 27.321, 27.337, and 27.341. These loads are applied to the rotor or rotors and any auxiliary surface as prescribed by this rule.

AC 27.341 § 27.341 GUST LOADS.

a. Explanation.

(1) The rotorcraft must be substantiated for the loads derived from 30 feet per second vertical gusts from hovering to 1.11 V_{NE} (i.e., V_D).

(2) Gust loads for any horizontal stabilizing surface should be derived for vertical gusts, upward and downward.

b. Procedures.

(1) Either sharp-edged (instantaneous) gusts or sharp-edged gusts modified by an alleviation (attenuation) factor may be used for calculating aerodynamic loads for the rotorcraft and any installed stabilizing surfaces. The following conditions may be used:

(i) Vertical gusts may be considered normal to the flight path of the rotorcraft except during hover or low speed flight (20 knots or less) when the gusts may be assumed normal to the longitudinal axis of the rotorcraft.

(ii) A primary effect of encountering the gust is to change the lift of the rotors and rotorcraft surfaces. Of primary concern is the gust load or lift created by the main rotor or rotors. The lift increment of the horizontal stabilizing surface and fuselage is generally negligible when compared to the rotor and may be neglected for the rotorcraft gust load determination if proven negligible by analysis.

(iii) The rotorcraft shall be assumed in stabilized level flight prior to meeting the gust.

(iv) The gust velocity may be assumed uniform across the rotorcraft.

(v) Gust loads on the stabilizing surfaces are required as stated in paragraph AC 27.413.

(2) The rotorcraft design maneuvering load factors may generally exceed the design gust load factors calculated in compliance with this rule. This may be attributed to the small incremental change in lift due to the 30 FPS gust. Nonetheless, design gust loads for the rotorcraft shall be calculated as specified in the rule to ensure the rotorcraft maneuvering load factors do, in each case, exceed the design gust load factor.

(3) For further information about rotorcraft gust response characteristics, see Paper No. 9 presented at the AHS/NASA -Ames Specialist's Meeting on Rotorcraft Dynamics, February 13-15, 1974. The paper, entitled, "Helicopter Gust Response Characteristics Including Unsteady Aerodynamics Stall Effects," was written by P.J. Arcidiacono, R.R. Berquist, and W.T. Alexander, Jr. References listed in the paper may be helpful also.

AC 27.351 § 27.351 (Amendment 27-26) YAWING CONDITIONS.

a. Explanation. The standard was added by Amendment 27-26. It requires proof of a rotorcraft "structural" yaw or sideslip design envelope. This sideslip envelope should cover minimum forward speed or hover to the lesser of V_H or V_{NE} for "power-on" condition, not "power-off" since V_H is a part of the standard. The rotorcraft should be structurally safe for the thrust capability of the directional control system as stated.

(1) The rotorcraft structure should be designed to withstand the loads for the specified yaw conditions. The standard does not require a structural flight demonstration. It is a structural design standard.

(2) Maximum displacement of the directional control, except as limited by pilot effort (130 pounds derived from § 27.397(a)), is required for the conditions cited in the standard. A control system rate limiter or a yaw damper may be used as part of the type design required equipment, if elected. The total displacement is therefore a function of time as well as the maximum effort applied such as 130 pounds.

(i) At low airspeeds from 0 to 0.6 V_{NE}, 90° yaw (sideward flight) is specified as the design limit.

(ii) At high airspeeds (V_H or V_{NE}), stabilized yaw angle (stabilized sideslip) or 15° sideslip, whichever is less, is specified to be substantiated.

(iii) At high airspeeds, the maximum tail rotor thrust will be combined with the vertical (directional) stabilizer surface load, if a stabilizer is used, as specified by § 27.351(b)(1).

(iv) At high airspeeds, while the rotorcraft is in the sideslip condition, the directional control is then returned to the neutral position, attendant with the flight condition. The tail rotor thrust will be added to the restoring force of the vertical stabilizer.

(v) Both right and left yaw conditions should be proven.

b. Procedures.

(1) Many of the current single main rotor rotorcraft designs have vertical (directional) stabilizing surfaces. These surfaces may be solely vertical stabilizing fins as on the Bell Model 206 or a swept vertical extension of the tail boom as on the Hiller Model FH1100. The Hiller FH1100 tail surface houses the tail rotor drive shaft and the tail rotor output gearbox.

(i) For vertical stabilizers, the airloads may be assumed independent of the tail rotor thrust.

(ii) For vertical stabilizers that house the tail rotor output gearbox, such as the Hiller Model FH1100, the tail surface air loads will add to or subtract from the tail rotor thrust according to the flight condition under consideration.

NOTE: For one example: At stabilized yaw to the right (left pedal depressed to limit) (§ 27.351(b)(2)), the tail rotor thrust moment should equal the restoring moment of the tail boom, vertical stabilizer, and main rotor torque. As stated by § 27.351(b)(3), the tail rotor thrust moment then is added to the vertical stabilizer restoring moment. The addition of tail rotor thrust (§ 27.351(b)(3)) and vertical stabilizer load is generally one of the critical design conditions for the fuselage/tail boom.

(iii) For vertical stabilizers or fins that have an offset incidence angle with respect to the rotorcraft axis, the vertical fin moment is added, or subtracted as applicable, to the tail rotor thrust moment. The condition stated in § 27.351(b)(1) may result in adding the fin load to the tail rotor thrust.

(iv) Low airspeed maneuvers, such as sideward, rearward, and hover turns over a spot, typically impose insignificant aerodynamic loads on the fuselage and/or tail boom. The aerodynamic loads at V_H or V_{NE}, whichever is required, are generally the significant aerodynamic design loads.

(v) A rational logical assessment of the various yaw conditions may be used to reduce the load derivation and analysis workload for critical rotorcraft design conditions.

(vi) The rotorcraft structure should be analyzed and/or tested for loads derived from the critical design conditions.

(vii) A simple structural design envelope may be derived from these design data. If the right or left yaw limits are not very different, common and conservative design limits may be used. A sample yaw/forward speed diagram, as derived from design analysis of the characteristics of a hypothetical rotorcraft, is presented in figure AC 27.351-1. A table of values would also suffice. This figure reflects characteristics which include a 90° yaw when the directional control inputs are applied at low airspeeds (up to 0.6 V_{NE}) and 15° yaw when they are applied at the lesser of V_{NE} or V_H, with a straight line variation from 0.6 V_{NE} to V_H or V_{NE}. The rotorcraft does not need to be capable of attaining the 90° and 15° yaw. They should be considered as the maximum sideslip limits.

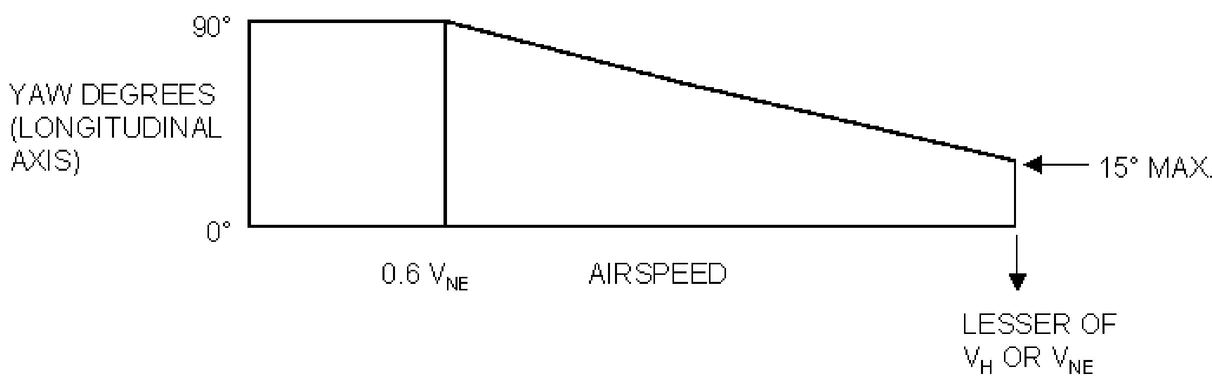


FIGURE AC 27.351-1 SAMPLE YAW/FORWARD SPEED DIAGRAM

(viii) During flight test evaluations, yaw angles have been measured using a yaw angle probe (swiveling vane type) on a nose boom. Both a visual readout for the pilot and a record, such as an oscillograph trace, have been used. This test may be conducted in the flight test program or in the flight load survey program. This record should confirm the yaw angle used in design as conservative with respect to operational and actual flight characteristics. However, this test is not a requirement.

(2) FAR § 27.351(b)(1) incorrectly references § 27.395(a) for the maximum pilot forces. The correct reference should be § 27.397(a).

AC 27.361 § 27.361 (Amendment 27-23) ENGINE TORQUE.

a. Explanation.

(1) The rotorcraft shall be designed for limit engine torque values, as prescribed by the rule, to account for maximum engine torque, including certain transients and torsional oscillations. Amendment 27-23 separated the standard into paragraphs for turbine and reciprocating engine limit torque values.

(2) Turbine engine limit torque for design purposes (Amendment 27-23) was redefined into four cases and the torque values determined will be used. For example, sudden engine stoppage is introduced as one of the cases which is applied to the engine and the engine suspension and restraint system. Emergency operation of governor-controlled turboshaft engines is another case.

(3) Torque factors are also specified for reciprocating engines having two or more cylinders in paragraph (b) of the standard.

(4) Sections 27.547(e)(1)(ii) and 27.549(d), respectively, refer to the application of engine torque to design of main rotor structure and engine mount and adjacent structure.

b. Procedures.

(1) The engine torque associated with the maximum continuous (MC) power condition for reciprocating engines should be multiplied by the appropriate torque factor to obtain the limit engine torque value used for structural substantiation of the rotorcraft.

(2) The torque values associated with MC power at the minimum power-on RPM limit should be used. Maximum power-on speed limit will result in a lower torque value when calculating torque from design horsepower values. However, due to piston engine power output characteristics, an engine may produce a higher torque at higher engine speeds contrary to the previous statement. The torque factor should account for this characteristic.

(3) Turbine engine limit torque values are determined for the four cases specified. Two cases are related to the endurance test of §§ 27.923 and 27.927.

(4) For sudden stoppage of turbine engines the engine manufacturers can reasonably provide FAA/AUTHORITY approved data to the applicant on inertia of rotating parts and the deceleration time expected in the event of sudden engine stoppage. This condition usually generates critical loads in the engine mounting and restraint system. These manufacturer's data should be acceptable for use in compliance with this part of the standard.

SUBPART C - STRENGTH REQUIREMENTS

CONTROL SURFACE AND SYSTEM LOADS

AC 27.391. § 27.391 CONTROL SURFACE AND SYSTEM LOADS--GENERAL.

a. Explanation. This general standard concerns requirements for design loads of tail rotors, control or stabilizing surfaces, and their control system.

b. Procedures. The design criteria and/or the design loads report shall contain the loads dictated by the referenced rules. (See paragraphs AC 27.395, AC 27.397, AC 27.399, AC 27.401, AC 27.403, AC 27.411, and AC 27.413.)

AC 27.391A. § 27.391 (Amendment 27-26) GENERAL.

a. Explanation. Amendment 27-26 adds an explicit reference to § 27.427, Unsymmetrical Loads (paragraph AC 27.427), to clarify that substantiation for unsymmetrical loads is a general control surface requirement. A reference to § 27.399, Dual Control System (paragraph AC 27.399), is also added for clarification. In addition, §§ 27.401, 27.403, and 27.413 were removed by this amendment since these references and requirements were adequately addressed in other standards.

b. Procedures. The referenced AC paragraphs become paragraphs AC 27.395, AC 27.397, AC 27.399, AC 27.411, and AC 27.427.

AC 27.395. § 27.395 CONTROL SYSTEM.

a. Explanation. Control system design loads and the application of these loads are contained in this rule.

(1) Paragraph (a) of the rule specifies the way or means of reacting the minimum design loads specified in §§ 27.397 and 27.399 (for dual control systems). Except reduced design loads, not less than 0.60 of those specified in §§ 27.397 and 27.399 for dual control system, may be used as specified. The standard also applies to those control systems that may have more than one stop in a system. The design loads must be imposed on the system from the pilot's control to any stop in the control system.

(2) Minimum design loads imposed on the control system from a stop to a rotor blade or a control surface or device shall be:

(i) The maximum pilot forces obtainable in normal operation; and

(ii) If low operational loads may be exceeded as noted in § 27.395(b)(2), the system shall support without yielding 0.60 of the loads specified in §§ 27.397 and 27.399 for dual control systems.

(3) Section 27.695 concerns standards for a power boost and power-operated control system. This standard, in effect, imposes a fail-safe standard for hydraulic aspects of a control system. Where appropriate to a particular design, the control system must therefore sustain without yielding, the maximum output force of the actuator when complying with § 27.395(a). The pilot input forces are not added to the actuator output forces according to this standard for normal category rotorcraft. These forces are independently applied to the control system.

(4) Control system design features and tests requirements are found in §§ 27.619 and 27.625, respectively. Special factors such as casting, bearing, and fitting factors that may be appropriate for the design are contained in §§ 27.619 and 27.625, respectively.

b. Procedures.

(1) The design criteria and/or a design loads report that includes the primary control system design loads should be submitted for FAA/AUTHORITY approval.

(2) The rotorcraft control system may be tested to ultimate design loads or may be analyzed for the ultimate design loads. See paragraph AC 27.307.

(i) A static test proposal for testing the control system to show compliance with the rules should be approved before conducting the test. Where compliance is to be determined by tests, limit load tests, as discussed in paragraph AC 27.681, and/or ultimate load tests may be performed. Test results shall be documented.

(ii) If tests are not conducted, a structural analysis of the control system is required. Appropriate factors from §§ 27.623 and 27.625 must be used as specified. Tests may not be required when adequate similarity of systems and support structure is determined and where adequate structural analysis is furnished.

(3) If a part of the control system is not stiff or rigid enough to react the design loads specified in §§ 27.397 and 27.399, that part of the system may be substantiated for lower loads as prescribed.

(i) The limit design loads are those loads specified in §§ 27.397 and 27.399;

(ii) The maximum that can be obtained in normal operation and that is allowed by the system; except

(iii) The limit design loads may not be less than 0.60 of the limit pilot forces specified.

(iv) For example, if a small control surface or servo tab is lightly loaded, its control system must be stiff enough to react the control surface loads and to provide surface deflection to control the rotorcraft. The normal operational loads may be very low, such as 10 pounds maximum. Nonetheless, the design limit load shall be 0.60 times the limit single pilot forces specified in § 27.397. Note that the system must not yield under these loads.

(v) For example, if a dual but primary manual control system such as a tail rotor control is lightly loaded, the control system, from the stops to the rotor blades, may be designed for minimum loads equal to 0.60 times the limit dual pilot forces specified in § 27.399.

(vi) If a power actuator is a part of a rotor control system, the design limit force for the affected parts shall be the maximum output force of the actuator at any operational condition (including any load/pressure after a single failure in the hydraulic system).

(4) Controls proof and operation test is required by §§ 27.307(b)(2) and (b)(3), 27.681, and 27.683. This test is conducted using the design limit loads approved under § 27.395. (See paragraphs AC 27.681 and AC 27.683.)

AC 27.395A. <u>§ 27.395 (Amendment 27-26) CONTROL SYSTEM</u>.

a. <u>Explanation</u>. Amendment 27-26 extensively rewrites § 27.395(b) to more clearly incorporate design condition loads for typical powered control systems. New requirements include substantiation for loads resulting from "each normally energized power device, including any single power boost or power activator failure in the control system." There are also new minimum loads for control system designs in which operational loads may be exceeded through jamming, ground gusts, control inertia, or friction. The old loads were 0.60 times the limit pilot forces of § 27.397; the new loads are 100 percent of the limit pilot forces specified in § 27.397.

b. <u>Procedures</u>. The procedures of paragraph AC 27.395 continue to apply except that the increased loads in § 27.395(b)(4) of 100 percent of limit pilot forces are specified for systems where operational loads may be exceeded by jamming, ground gusts, control inertia, or friction.

AC 27.397. <u>§ 27.397 (Amendment 27-11) LIMIT PILOT FORCES AND TORQUES</u>.

a. <u>Explanation</u>. Design forces are contained in the rule.

(1) Primary controls, pilot and copilot, should be designed for the limit pilot forces specified in paragraph (a) of the rule unless higher forces are used.

(2) For other operating controls, such as flap, tab, stabilizer, rotor brake, and landing gear, design limit forces are specified in paragraph (b).

b. Procedures.

(1) Design loads specified in the rule may be used in required structural tests and in any structural strength analysis of the control systems submitted in compliance with other rules.

(2) Operation tests of the control systems noted in other rules require application of these forces also.

AC 27.399. § 27.399 DUAL CONTROL SYSTEM.

a. Explanation. Design limit loads are specified for dual control systems. Pilot effort forces applied in opposition and in the same direction are required for dual control systems.

b. Procedures.

(1) Design loads specified in the rule may be used in required structural tests and in any structural strength analysis submitted for compliance with the other rules.

(2) Operation tests of the control systems, noted in other rules, require application of these forces also.

AC 27.401. § 27.401 (Amendment 27-3) AUXILIARY ROTOR ASSEMBLIES.

a. Explanation.

(1) For rotorcraft equipped with auxiliary rotors, normally called tail rotors, an endurance test is required by § 27.923, and structural strength substantiation is required. Section 27.401(b) specifically refers to structural strength substantiation of detachable blade systems for centrifugal loads resulting from maximum design rotor RPM.

(2) The rotor blade structure must have sufficient strength to withstand not only aerodynamic loads generated on the blade surface, but also inertial loads arising from centrifugal, coriolis, gyroscopic, and vibratory effects produced by this blade movement. Sufficient stiffness and rigidity must be designed into the blades to prevent excessive deformation and to ensure that the blades will maintain the desired aerodynamic characteristics. As a design objective, the structural strength requirements should be met with the minimum material. Excess blade weight imposes extra centrifugal loads

that may increase the operating stress levels. Blade weight and strength should be optimized. Even though a structural strength analysis for the blade design loads is required, a flight load survey and fatigue analysis are also required by § 27.571.

(3) Section 27.1509 defines the design rotor speed as that providing a 5 percent margin beyond the rotor operating speed limits.

b. Procedures.

(1) The endurance tests prescribed by §§ 27.923 and 27.927 require achieving certain speeds, power, and control displacement for the auxiliary (tail) rotor as well as the main rotor. The parts must be serviceable at the conclusion of the tests.

(2) Structural substantiation of the auxiliary (tail) rotor is required to ensure integrity for the minimum and maximum design rotor speeds and the maximum design rotor thrust in the positive and negative direction. Thrust capability of the rotor should offset the main rotor torque at maximum power as required by § 27.927(b).

(i) The maximum and minimum operating rotor speed, power-off, is 95 percent of the maximum design speed and 105 percent of the minimum design speed, respectively.

(ii) The rotor operating speed limits shown during the official FAA/AUTHORITY flight tests must include the noted 5 percent margin with respect to the design speeds.

(iii) The auxiliary rotor generally has a positive and negative pitch limit that ensures adequate directional control throughout the operating range of the rotorcraft. The power-off rotor speed limits are generally broader than the power-on rotor speed limits because of the required autorotational rotor speed characteristics. Thus, the auxiliary rotor design conditions concern the maximum and minimum design rotor speeds in conjunction with the maximum positive or negative pitch thrust, as appropriate. Thrust capability and precone angle of the rotor, if any, will significantly influence the rotor design loads. The variations in rotor design features and an example of substantiation would be too lengthy to include here. However, ANC-9, "Aircraft Propeller Handbook" contains principles that may be applied to tail rotor designs. Tail rotors may be considered a special propeller design.

(iv) Bearings are generally used in the tail rotor installation to allow flapping and feathering motion of the blades. The bearing manufacturer's ratings of these bearings must not be exceeded. Bearings generally used in main and tail rotors are classified as ABEC Class 3, 5, or 7. Class 7 is the highest quality presently available. Satisfactory completion of the endurance tests of §§ 27.923 and 27.927 is a means of proving that use of a particular bearing is satisfactory.

(v) The analysis must include appropriate special factors, casting factors, bearing factors, and fitting factors prescribed by §§ 27.619, 27.621, 27.623, and 27.625, respectively. The fitting factor of 1.15 must be applied in the analysis of the tail rotor installation.

AC 27.401A. § 27.401 (Amendment 27-27) AUXILIARY ROTOR ASSEMBLIES.

a. Explanation. Amendment 27-27 removed this section since the requirements are adequately addressed in §§ 27.337, 27.339, and 27.341.

b. Procedures. The policy material pertaining to this section is retained as supplemental information.

AC 27.403. § 27.403 AUXILIARY ROTOR ATTACHMENT STRUCTURE.

a. Explanation.

(1) The auxiliary rotor attachment structure(s), which is considered to include gearboxes, must be designed to withstand design limit loads that occur in flight and on landing. These design loads that generally consist of the following must be established for the particular flight and landing condition under consideration.

(i) Inertia loads generated by linear and angular accelerations of the auxiliary rotors and their gearboxes, combined with--

(ii) Thrust and torque loads developed by the auxiliary rotors.

The linear and angular acceleration loads imposed by the weight of the tail rotor and gearbox are generally derived from airframe loads data. Thrust and torque output of the tail rotor are derived during external aerodynamic and landing loads development for pertinent flight and landing conditions.

(2) General rules related to proof of structure loads and factor of safety are §§ 27.307, 27.301, 27.303, and 27.305.

b. Procedures.

(1) The angular and linear acceleration loads combined with appropriate tail rotor thrust and torque for the critical conditions shall be imposed on the tail rotor gearbox mount lugs, the airframe mounting structure, and the attaching hardware.

(2) The yaw and maximum power climb conditions are generally critical. Landing and maneuvering conditions with and without power may also impose high inertia and rotor thrust and torque loads on the attachment structure.

(3) The derivation of the loads and conditions is too extensive to include here. Additional information can be found in the U.S. Army Material Command Report AMCP 706-201, "Engineering Design Handbook: Helicopter Engineering, Part One, Preliminary Design."

AC 27.403A. § 27.403 (Amendment 27-27) AUXILIARY ROTOR ATTACHMENT STRUCTURE.

a. Explanation. Amendment 27-27 removed this section since the requirements are adequately addressed in §§ 27.337, 27.339, 27.341.

b. Procedures. The policy material pertaining to this section is retained as supplemental information.

AC 27.411. § 27.411 GROUND CLEARANCE: TAIL ROTOR GUARD.

a. Explanation.

(1) The rule requires specific protection to prevent the tail rotor from contacting the landing surface during a normal landing if it is possible that the tail rotor will contact the surface. The rule states that it must be impossible for the tail rotor to contact the surface during a normal landing.

(2) If a guard is required, the guard and its supporting structure must withstand suitable design loads.

(3) Section 27.501(c)(1) contains skid landing gear drag requirements that may be applied to the guard design loads.

b. Procedures.

(1) The applicant may submit sketches or drawings showing probable clearance with typical level landing surfaces during normal landings. Typical attitudes such as nose-high autorotation, or autorotation with power-on landing, or other possible tail-low attitudes should be investigated. If the drawings or sketches reveal that it is not likely the tail rotor will contact the landing surface, this minimum clearance with the landing surface may be confirmed during official FAA/AUTHORITY flight tests, such as HV and landing tests. The clearance may be confirmed by having a frangible device of suitable length (i.e., a balsa wood dowel) extending beyond the guard and attached to the tail rotor guard or other appropriate fuselage part. If the device is not damaged, broken, or no contact is made with the surface, compliance has been demonstrated.

(2) If it is possible for the tail rotor guard to contact the landing surface, suitable design loads must be established for the guard. ANC-2a dated March 1948, "ANC Bulletin Ground Loads," paragraph 6.4, entitled "Tail Bumper Criteria," is an acceptable

means of deriving the rotorcraft kinetic energy that shall be absorbed by the guard. This method is noted here for convenience.

(i) The tail rotor guard shall be able to absorb the kinetic energy of the rotorcraft in its most unfavorable CG position in the tail-down landing attitude. The kinetic energy that the tail rotor guard should be capable of absorbing may be determined by the following:

$$KE = \frac{WV_S^2}{2g} \times \frac{K_Y^2}{(K_Y^2 + 1_B^2)}$$

where-- V_S = vertical speed ft/sec, derived from § 27.725(a)
K_Y = pitching radius of gyration - ft from pitching axis
1_B = distance from most critical CG location to the guard or bumper contact point - ft
W = gross weight less rotor lift from § 27.473(a) - lbs
g = 32.2 ft/sec^2

(ii) Other, more recent, analytical techniques (most utilizing computer programs) may, of course, be used rather than the ANC-2a means after proper substantiation for applicability and validity.

(iii) The tail rotor guard should not fail when the limit and ultimate load, which is derived from a combination of the limit kinetic energy and the guard resulting limit deflection required to dissipate the energy, is imposed on the guard and the rotorcraft tail (see § 27.305).

(3) Substantiation of the guard, skid, or bumper for the design loads derived may be accomplished by test or analysis as stated in § 27.307(a).

(4) Several rotorcraft tail rotor guards are installed solely for the protection of ground personnel from the rotating tail rotor. For guards installed for this purpose, the applicant should use prudent and reasonable design loads and features. Such guards should not present a hazard to the rotorcraft because of its design features.

AC 27.413. § 27.413 STABILIZING AND CONTROL SURFACES.

a. Explanation. Minimum design loads are specified for stabilizing as well as control surfaces.

(1) Paragraph (a) of the rule requires application of minimum empirical design loads, application of critical maneuvering loads, and application of critical maneuvering loads combined with vertical gust loads (30 feet per second or 17.8 knots per § 27.341).

(2) Paragraph (b) requires load distributions that closely simulate actual pressure distributions. Both spanwise and chordwise distributions are intended.

(3) These surfaces are used for stability and control thereby hopefully extending the CG range and increasing the airspeed of modern designs.

(4) To "closely simulate actual pressure condition" on the surfaces, unsymmetrical loads are also required on horizontal surfaces. An arbitrary distribution, if conservative, may be used.

(5) It is noted § 27.571 requires fatigue substantiation of the flight structure which will include control and stabilizing surfaces.

(6) If the surface is controllable, a proof and operation test of the surface control system is required by §§ 27.681 and 27.683.

b. Procedures. Modern rotorcraft designs have generally employed a fixed or a wholly movable, not split or divided, stabilizing or control surface.

(1) Design Loads.

(i) Limit loads of 15 pounds per square foot will apply up to approximately a 90-knot design airspeed. Above a 90-knot design airspeed ($1.11V_{NE}$), the coefficient ($C_N = 0.55$) imposes higher limit loads on the surface. The coefficient C_N is assumed normal to the chordline of the section.

(ii) In addition, combined maneuvering and vertical up or down gust loads may impose the highest limit loads on the control surfaces of rotorcraft. This is attributed to the change in angle of attack and change in resultant airspeed.

(iii) The applicant may choose to derive the limit loads using maximum aerodynamic coefficients for the surface under consideration at the maximum design airspeed combined with a 17.8-knot gust. This would be acceptable provided these design loads exceed the minimum loads derived from a $C_N = 0.55$ at design airspeed or exceed 15 pounds per square foot load on the surface.

(2) The load distribution on the surface should closely simulate actual pressure distributions.

(i) The spanwise load may be rectangular, or other acceptable conservative distributions may be used. The method developed by O. Schrenk in NACA TM 948, 1940, is an acceptable method for approximation of spanwise distribution.

NOTE: The method is valid for aspect ratios of 5 through 12 and for rectangular planforms such as used on rotorcraft, other planforms may be acceptable as prescribed in the TM.

(ii) The chordwise distribution appropriate for the aerodynamic shape or a conservative distribution should be used.

(iii) The flight load survey conducted under § 27.571 may be used to confirm design parameters and possible load distribution data. On controllable surfaces, the pitching moment (control loads) may be measured for fatigue substantiation of the control system. The control stabilizing surfaces may be subject to loads measurement and possible fatigue tests for fatigue substantiation also.

(3) Proof of the structure for the required loads is specified in §§ 27.301, 27.303, 27.305, and 27.307. Tests or analysis may be used as prescribed. If analysis is used, fitting factors and other appropriate factors prescribed by the rules of §§ 27.625, 27.621, and 27.623 will be required in the analysis.

AC 27.413A. <u>§ 27.413 (Amendment 27-27) STABILIZING AND CONTROL SURFACES</u>.

a. <u>Explanation</u>. Amendment 27-27 removed this section since the requirements are adequately addressed in §§ 27.337, 27.339, and 27.341.

b. <u>Procedures</u>. The policy material pertaining to this section is retained as supplemental information especially as reference material for paragraph AC 27.341 (§ 27.341).

AC 27.427. <u>§ 27.427 (Amendment 27-27) UNSYMMETRICAL LOADS</u>.

a. <u>Explanation</u>. Amendment 27-26 added the standard and Amendment 27-27 amended it. Minimum unsymmetrical design loads are specified for horizontal tail surfaces and also vertical tail surfaces whenever they support the horizontal tail surfaces.

(1) Loads are derived by rational analysis, or for earlier certification bases, the prescribed empirical loads of § 27.413 may be used. Section 27.413 was removed by Amendment 27-27 since the requirements are adequately addressed in §§ 27.337, 27.339, and 27.341.

(2) Rational loads, appropriate for the aerodynamic surfaces, should be distributed according to the standard.

(3) When vertical tail surfaces support the horizontal tail surfaces, the vertical tail surfaces and supporting surfaces are required to support the critical combination of vertical and horizontal surface loads.

b. Procedures. Two basic loading conditions are required by § 27.427 for each of the two basic empennage configurations.

(1) Horizontal surfaces supported by the tail boom or fuselage. Structural substantiation should be provided for all six combinations shown in figure AC 27.427-1. All of these empirical loading distributions should be used unless rational analysis shows one or more of each set of conditions to be non-critical or equal or more realistic distributions are substantiated. Rectangular spanwise air load distribution should be used unless more rational distribution is substantiated. If end plates are used, the air loads should be distributed accordingly.

(i) First unsymmetrical loading condition:

(A) 100 percent of the flight load is applied to one side of the plane of symmetry; and 0 percent of the flight load is applied to the other side of the plane of symmetry.

(B) For surfaces with end plates or other similar devices, the load distribution will be changed accordingly.

(ii) Second unsymmetrical loading condition:

50 percent of the flight load is applied to one side of the plane of symmetry acting up; and 50 percent of the flight load is applied to the other side of the plane of symmetry acting down.

(2) Horizontal surfaces supported by a vertical surface. Structural substantiation should be provided for all six combinations shown in figure AC 27.427-2. All of these empirical loading distributions should be used unless rational analysis shows one or more of each set of conditions to be non-critical or equal or more realistic distributions are substantiated. Rectangular spanwise air load distribution should be used unless more rational distribution is substantiated. If end plates are used, the air loads should be distributed accordingly.

(i) First unsymmetrical loading condition:

100 percent of the flight load is applied to one side of the plane of symmetry; and 0 percent of the flight load is applied to the other side of the plane of symmetry.

(ii) Second unsymmetrical loading condition:

50 percent of the flight load is applied to one side of the plane of symmetry acting up; and 50 percent of the flight load is applied to the other side of the plane of symmetry acting down.

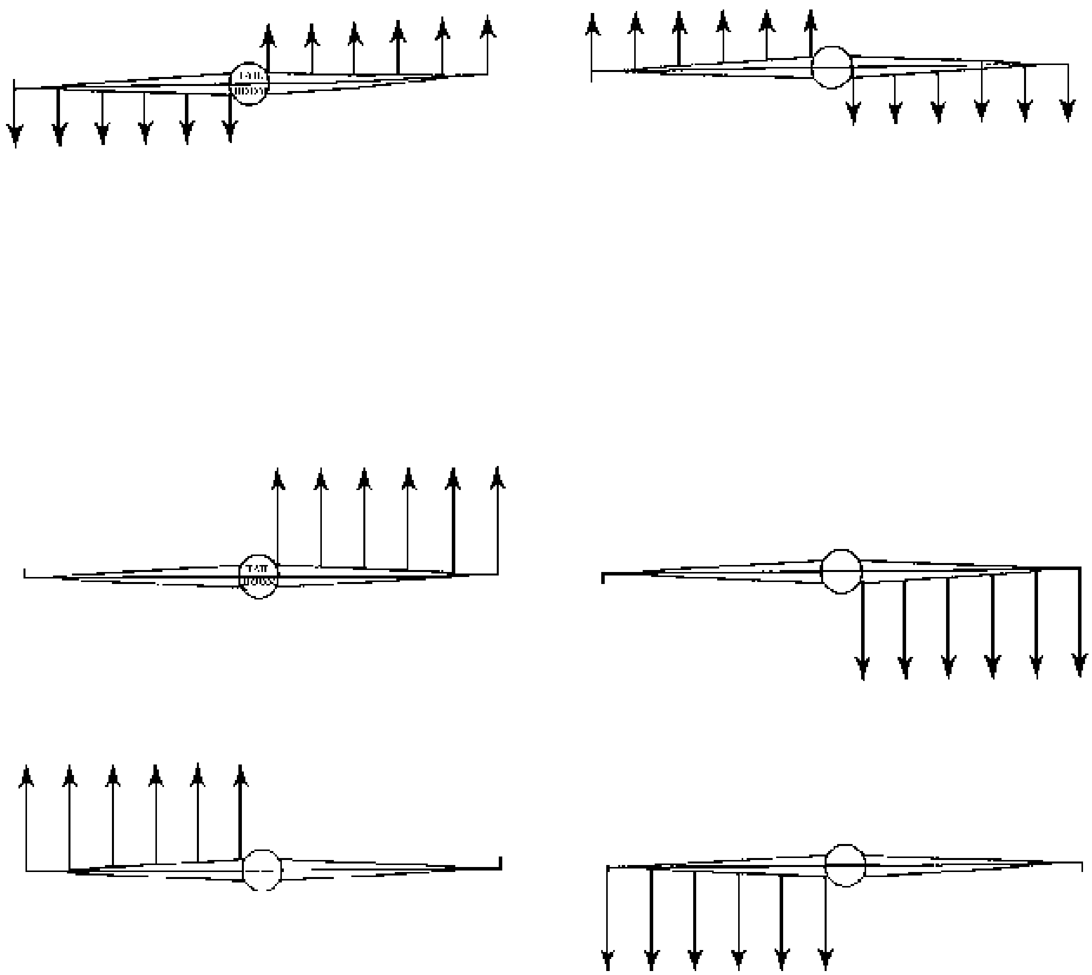


Figure AC 27.427-1 (View Looking Forward)

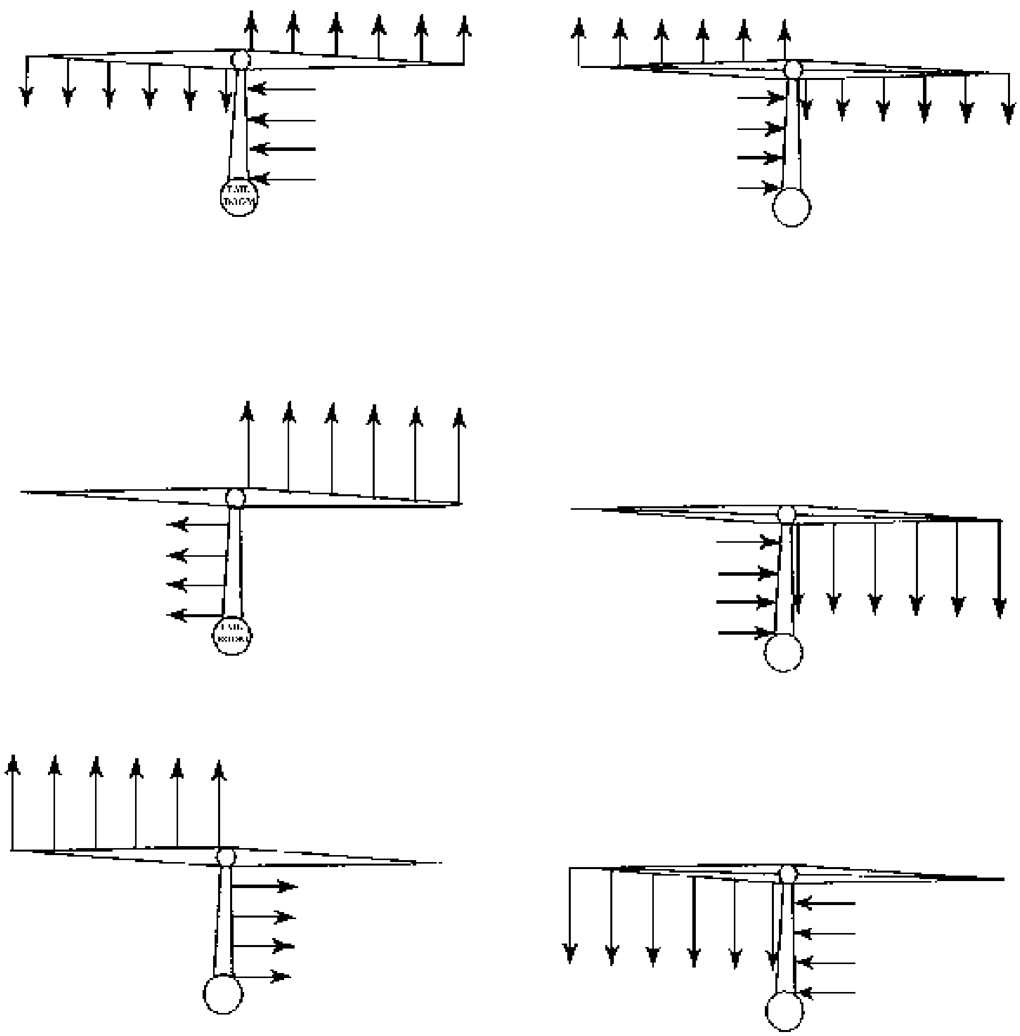


Figure AC 27.427-2 (View Looking Forward)

SUBPART C - STRENGTH REQUIREMENTS

GROUND LOADS

AC 27.471 § 27.471 GROUND LOADS--GENERAL.

a. Explanation. This regulation specifies that limit ground loads must be considered which are:

(1) External loads caused by landing (ground) conditions for skid and wheel landing gear equipped rotorcraft and by ground taxiing loads as specified in § 27.235 for wheel landing gear equipped rotorcraft.

(2) Loads considering the rotorcraft structure as a rigid body.

(3) Loads in equilibrium with linear and angular inertia loads.

(4) The critical center of gravity "must be selected so that the maximum design loads are obtained in each landing gear element."

b. Procedures.

(1) The standards to be considered are specified in §§ 27.473 through 27.505. These associated standards cover landing gear arrangements, landing conditions, and ground loading conditions (for wheel landing gear rotorcraft).

(2) Drop tests may be used to verify landing load factors. (See paragraph AC 27.725.)

(3) The application of the design loads derived from the landing load factors will be as specified for each element affected by landing or ground loading conditions (for wheel landing gear rotorcraft).

(4) During the applicant's flight test program, the landing load factors for skid and wheel landing gear rotorcraft and taxiing load factors for wheel landing gear rotorcraft are monitored to assure the design load factors used are adequate. See paragraph AC 27.235 of this document for § 27.235 policy.

AC 27.473 § 27.473 (Amendment 27-2) GROUND LOADING CONDITIONS AND ASSUMPTIONS.

a. Explanation. The rotorcraft is to be designed for the maximum weight. A rotor lift of two-thirds of the design maximum weight may be used. The minimum limit landing load factor is determined by the drop tests of § 27.725.

b. Procedures. Loads for the landing conditions are derived considering mass (equal to the maximum weight) and rotor lift (equal to two-thirds of the maximum weight) acting through the center of gravity throughout the landing impact. Unbalanced external loads resulting from asymmetric loading conditions are reacted as specified in the individual subparagraphs. The rotorcraft must be substantiated for ultimate landing loads by either test or analysis utilizing an ultimate load factor of 1.5 applied to the limit load factor of not less than that substantiated under § 27.725.

AC 27.475 § 27.475 TIRES AND SHOCK ABSORBERS.

a. Explanation. This section specifies the tire and shock absorber position to be used in ground load derivations.

b. Procedures. Ground loads are to be derived with the tires in static (1g) position and the shock absorbers "in their most critical position." The determination of the "most critical position" for the shock absorbers generally requires a load versus deflection test or analysis of the shock absorber system and a determination of the effect of both load and deflections on the shock absorber, attachment structure, and substructure designed by ground loads.

AC 27.477 § 27.477 LANDING GEAR ARRANGEMENT.

a. Explanation. This section specifies the individual standards to be used for ground load conditions for rotorcraft having two wheels aft and one or more wheels forward of the center of gravity.

NOTE: Section 27.497 gives ground loading conditions for landing gear with tail wheels, and § 27.501 gives ground loading conditions for landing gear with skids.

b. Procedures. The ground loading conditions of §§ 27.235, 27.479 through 27.485, and 27.493 will be used for rotorcraft having two wheels aft and one or more wheels forward of the center of gravity. This includes forward wheels on separate axles.

AC 27.479 § 27.479 LEVEL LANDING CONDITIONS.

a. Explanation. This section provides explicit level landing load criteria for landing gear with two wheels aft and one or more wheels forward of the center of gravity.

(1) Level landings--

(i) Each wheel contacting the ground simultaneously; and

(ii) Aft wheels contacting the ground with forward wheels just clear of the ground.

(2) Application of loads--

(i) Maximum design vertical loads applied alone; and

(ii) The maximum design vertical loads applied with a drag load of at least 25 percent of the vertical load (applied at the ground contact area).

(3) A 40 percent/60 percent load distribution between wheels for configurations having two forward wheels including quadricycle. This distribution between wheels on a common axis is to be applied for the conditions of vertical loads only and for vertical loads combined with drag loads of 25 percent of the vertical loads.

(4) Aircraft pitching moments are to be reacted by the forward landing gear for simultaneous wheel contact or by the angular inertia forces when the forward landing gear is clear of the ground as specified.

b. Procedures.

(1) The specified loading conditions will be used in load derivations.

(2) The critical center of gravity condition will be used for each gear and gear support structure.

(i) The aft center of gravity condition with the forward gear clear will normally be critical for the aft gear and gear supports.

(ii) The forward center of gravity condition with each gear contacting the ground simultaneously will normally design forward gear elements critical for vertical loads.

(iii) The forward center of gravity condition with the forward gear clear may result in high load factors, angular plus linear, that will greatly affect security of items of significant mass.

AC 27.481 § 27.481 TAIL-DOWN LANDING CONDITIONS.

a. Explanation. This section provides the criteria for tail-down landing conditions; i.e., “the maximum nose-up attitude allowing ground clearance” with ground loads acting “perpendicular to the ground.”

b. Procedures.

(1) The tail-down landing condition will be used to check (by analysis or test) for criticality of landing gear or support structure. This attitude generally creates the highest forward loads on the main landing gear in combination with vertical loads.

(2) The tail-down landing condition may be the critical condition for both landing load factor and for energy absorption by the main gear. Section 27.725 requires that "each landing gear must be tested in the attitude simulating the landing condition that is most critical." Where questions exist as to the critical attitude, both level landing and tail-down landing attitudes should be used in drop tests required by § 27.725.

AC 27.483 § 27.483 ONE-WHEEL LANDING CONDITIONS.

a. Explanation. This section gives the condition to be used for one-wheel landing conditions. Only the vertical load condition of § 27.479(b)(1) is required.

b. Procedures. The one-wheel landing condition is generally critical for the landing gear-to-fuselage attachments and the landing gear elements between the attachments. Unbalanced external loads are reacted by rotorcraft inertia.

AC 27.485 § 27.485 LATERAL DRIFT LANDING CONDITIONS.

a. Explanation.

(1) This section provides the loading conditions which impose side (and vertical) loads on the landing gear. A level landing attitude is specified. Two main conditions required are--

(i) Only the aft wheels in contact with the ground; and

(ii) All wheels contacting the ground simultaneously.

(2) Loads. The vertical loads to be applied with the side loads are specified as "one-half of the maximum ground reactions of § 27.479(b)(1)." These vertical loads are the level landing loads considering both contact and noncontact with the ground by the forward wheels.

(i) One side load condition is specified as "0.8 times the vertical reaction acting inward on one side and 0.6 times the vertical reaction acting outward on the other side" when only the aft wheels contact the ground.

(ii) The other side load condition (for all wheels contacting the ground) specifies the 80 percent inward/60 percent outward distribution for the aft wheels and 0.8 times (80 percent) the vertical reaction for the forward wheels.

b. Procedures. The loading conditions, as specified, are applied to the landing gear and attaching structure. The loads are applied at the ground contact point, except for full swiveling gear which has the load applied at the center of the axle. In other words, full swiveling gear is considered to have swiveled to a static position under the side load before the design vertical and side loads are achieved. The rotorcraft as well as the landing gear itself will be substantiated for these side load conditions.

AC 27.493 § 27.493 BRAKED ROLL CONDITIONS.

a. Explanation. This section provides two loading conditions for ground braking operations. Specific vertical loads in conjunction with drag loads (due to braking) are to be considered. The limit vertical load factor is 1.33 for condition of all wheels in contact with the ground and 1.0 for condition of aft wheels only in contact with the ground and nose wheel clear. The drag load on wheels with brakes is 0.8 times the vertical load or the drag load value based on limiting brake torque, whichever is less. The drag load value for limiting brake torque may be that determined in the performance testing to TSO C26 or equivalent, as required.

b. Procedures. The braking loads are calculated from the specified criteria with the shock absorbers in their static (normal) positions and with the drag loads applied at the ground contact point. Structural substantiation of the affected structure may be accomplished by test or analysis. If tests are used, the wheel and tire assembly is commonly replaced with a test fixture so the limit loads and static deflections specified can be more accurately controlled. The test specimen should be complete enough to ensure that the landing gear structure and the attach and backup structure are adequately substantiated.

AC 27.497 § 27.497 GROUND LOADING CONDITIONS: LANDING GEAR WITH TAIL WHEELS.

a. Explanation. This section provides the loading conditions for landing gear designs with tail wheels.

(1) Level landings are to consider the following:

(i) All wheels (main and tail) contacting the ground simultaneously, as well as only forward main wheels contacting the ground.

(ii) Maximum design vertical loads applied alone.

(iii) The maximum design vertical loads combined with a drag load of at least 25 percent of the vertical loads for both conditions.

(2) Nose-up landings with only the rear wheel or wheels initially contacting the ground must be considered unless shown to be extremely remote.

(3) Level landings on one forward wheel only are to be considered. Drag loads are not required.

(4) Side load conditions are imposed on the main wheels and tail wheels for level landing attitudes. Criteria for full swiveling and locked tail wheels are included in this standard.

(5) Braked roll conditions are specified for the level landing attitudes.

(6) Rear wheel turning loads are also specified for swiveling and locked tail wheels.

(7) Taxiway condition loads for the landing gear and rotorcraft are those that "occur when the rotorcraft is taxied over the roughest ground that may reasonably be expected in normal operation." The aircraft design load factors should not be exceeded during the evaluation. Section 27.235 contains an identical standard that applies to all types of wheel landing gear.

b. Procedures.

(1) The specified loading conditions are to be used in load derivations.

(2) The critical center of gravity condition is used for each gear and gear support structure.

(i) The forward center of gravity condition with the tail gear clear will normally be critical for the forward gear and gear supports.

(ii) The aft center of gravity condition with the tail gear clear should be checked for criticality of security of large mass items located forward of the center of gravity. Vertical and angular accelerations are additive under this landing condition.

(iii) The aft center of gravity condition with each gear contacting the ground simultaneously will generally design tail gear elements critical for vertical loads. The other conditions are generally less severe but must be proven.

(3) For tail-down landing procedures use § 27.481. The reference to "extremely remote" in § 29.497(d)(2) predates current §§ 25.1309, 29.1309, and AC 25.1309.1. This phrase has been used to require consideration of nose-up landings unless features of design are present which prevent nose-up landings or where such landings are unlikely during the life of the rotorcraft. (See paragraph AC 27.481.)

(4) Use § 27.483 for one-wheel landing procedures, paragraph AC 27.483.

(5) Use § 27.485 procedures for side load conditions, paragraph AC 27.485.

(6) Use § 27.493 procedures for braked roll conditions, paragraph AC 27.493.

(7) For rear wheel turning loads, swiveling of tail landing gears is allowed as in basic side load conditions. The side load is applied at the axle or, if the wheel is locked, the load is applied at ground contact. Rear wheels are loaded with the critical vertical static load in conjunction with an equal side load to substantiate the tail gear.

(8) Since the rotorcraft is to be designed for load factors that will not be exceeded during taxi tests or other conditions, an instrumented taxi test program will be necessary. (Use § 27.235, paragraph AC 27.235.)

AC 27.501 § 27.501 (Amendment 27-2) GROUND LOADING CONDITIONS: LANDING GEAR WITH SKIDS.

a. Explanation. This section provides the ground loading conditions for landing gear with skids. The loading conditions are similar to those for wheeled gear except for the following criteria which are unique to skid gears:

(1) Structural yielding of elastic spring members under limit loads is allowed.

(2) Design ultimate loads for elastic spring members need not exceed the loads obtained in a drop test with a drop height of 1.5 times the limit drop height. The rotorcraft and the landing gear attachments are subject to the prescribed design ultimate loads.

(3) The gear must be in its most critically deflected position (similar to § 27.475).

(4) Ground reactions are rationally distributed along the bottom of the skid unless otherwise specified. Section 27.501(f) concerns specific “concentrated” and arbitrary load conditions.

(5) Drag loads are 50 percent of vertical reactions rather than the 25 percent for wheeled gear.

(6) Side loads are 25 percent of the total vertical reaction rather than the 60 to 80 percent for wheeled gear.

(7) Side loads are applied to one skid only (inward acting and outward acting) with resulting unbalanced moment resisted by angular acceleration.

(8) A ground reaction load of 1.33 times the maximum weight is to be applied at 45° from the horizontal axis:

(i) Distributed among or between the skids;

(ii) Concentrated at the forward end of the straight portion of the skid tube; and

(iii) Applied only to the forward end of the skid tube and its attachment to the rotorcraft.

(9) A concentrated vertical load equal to one-half of the design limit vertical load is to be applied at a point midway between the skid tube attachments. This condition applies only to the skid tube and its attachment to the rotorcraft.

b. Procedures.

(1) The specified loading conditions are to be used in load derivations.

(2) The critical center of gravity conditions are to be used for each gear and gear support structure. Asymmetry of the skid tubes, cross tubes, and gear attachments is to be considered in determining the critical center of gravity condition.

(3) The rotorcraft and landing gear attachment must be substantiated for ultimate landing loads by either test or analysis utilizing an ultimate load factor of 1.5 in accordance with § 27.303. The elastic spring members may be analyzed or static tested for ultimate loads (and deflections) using either a factor of safety of 1.5 or one associated with an "ultimate" drop height of 1.5 times the limit drop height. Substantiation by "ultimate" drop tests may be used provided all combinations of critical parameters are included in the total substantiation effort. This method will require a series of tests using several test specimens or a limited number of drop tests plus further substantiations by static tests or analyses for additional critical conditions not covered by the drop test(s).

AC 27.501A § 27.501 (Amendment 27-26) GROUND LOADING CONDITIONS: LANDING GEAR WITH SKIDS.

a. Explanation. Amendment 27-26 relaxes the previous requirements in two cases by:

(1) Allowing the total sideload of § 27.501(d)(3) to be distributed "equally between skids" rather than being "applied along the length of one skid only;" and,

(2) Allowing the concentrated load of § 27.501(f)(2)(ii) to be distributed over the central 33.3 percent of the skid (between skid tube attachments) rather than being "concentrated at a point midway between the skid tube attachments."

b. Procedures. The previous procedures (through Amendment 27-19) continue to apply to Amendment 27-26 except use the new load distributions.

AC 27.505 § 27.505 SKI LANDING CONDITIONS.

a. Explanation. This is an optional requirement for ski operations. The regulation specifies vertical loads, side loads, and torque loads (M_Z) to be applied to ski installations. The four loading conditions to be applied at the pedestal bearings are:

(1) Simultaneous application of Pn, up load, and Pn/4, horizontal load.

(2) Up load of 1.33 P.

(3) Side load of 0.35 Pn.

(4) Torque load of 1.33 P (in foot-pounds) about the vertical axis through the centerline of the pedestal bearings.

NOTE: Where P is the maximum static weight on each ski and n is the limit load factor obtained from drop tests. The load factor obtained from wheel or skid landing gear drop tests may be used.

b. Procedures. Structural substantiation may be accomplished by static test or analysis using the specified loads. Skis generally have a limit load rating. The design loads derived for this standard must not exceed the rating. (TSO-C28 concerns, in part, standards for aircraft skis.)

SUBPART C - STRENGTH REQUIREMENTS

WATER LOADS

AC 27.521 § 27.521 FLOAT LANDING CONDITIONS.

a. Explanation. This is an optional requirement for float operations. The regulation specifies vertical loads, aft loads, and side loads to be applied to the float installations. The two loading conditions to be applied are:

(1) Up-load Condition.

(i) A vertical load appropriate to a landing load factor determined under § 27.473(b).

(ii) A resultant water reaction passes vertically through the aircraft CG.

(iii) An aft load equal to 25 percent of the vertical load.

(2) Side-load Condition.

(i) A vertical load equal to 75 percent of the vertical load for the up-load condition, equally divided among the floats.

(ii) A side load at each float equal to 25 percent of the vertical load specified for the side load condition.

b. Procedures.

(1) The vertical load factor is determined by drop tests in accordance with §§ 27.473(b) and 27.725. The floats may be drop tested, or they may be assumed to have the same load factor as wheeled gear which have been drop tested.

(2) Structural substantiation may be accomplished by either static tests or analysis using the specified loads. The load distribution on the floats may be realistic, based on hydrostatic pressure distributions, or conservative.

SUBPART C - STRENGTH REQUIREMENTS

MAIN COMPONENT REQUIREMENTS

AC 27.547 § 27.547 (Amendment 27-3) MAIN ROTOR STRUCTURE.

a. Explanation. This regulation requires the main rotor structure to be designed to the static load requirements of §§ 27.337 through 27.341 (vertical maneuvering loads and vertical and horizontal gust loads). In addition, the main rotor blades, hubs, and flapping hinges are specified to be designed for impact forces of each blade against its stop during ground operation and for specified limit torque at any rotational speed including zero. The torque forces (from the drive system) are distributed to the rotor blades as specified.

b. Procedures.

(1) Substantiation in compliance with this standard is accomplished by application of the flight loads of §§ 27.337 through 27.341 and the torque loads of § 27.361 to the rotor structure by stress analyses and/or static tests. The use of wind tunnel data as well as flight loads survey data may be used to generate and/or check the external load magnitudes and distributions.

(2) Where new materials are used in the main rotor structure, such as composites containing plastics, the effects of temperature and humidity are to be considered in accordance with § 27.603, and the effects of uncertainties in manufacturing processes or inspection methods are to be considered in accordance with § 27.619. More experience is available for metallic materials, but § 27.603 requires that metallics be suitably protected against the effects of environmental conditions.

(3) The design impact forces of each blade must be imposed against its stop or stops. Appropriate monitoring of the blades, hubs, flapping hinges, and stops during laboratory tests, ground endurance tests, and flight tests should ensure that the stops are sufficient for ground operation loads. The design torque loads are derived as prescribed.

AC 27.549 § 27.549 (Amendment 27-3) FUSELAGE, LANDING GEAR, AND ROTOR PYLON STRUCTURE.

a. Explanation. This regulation requires that the fuselage, landing gear, and rotor pylon (including the tail fin, if any) be designed to withstand the flight loads of §§ 27.337 through 27.351, the ground loads of §§ 27.235, 27.471 through 27.497, skid loads of § 27.501, ski loads of § 27.505, water loads of § 27.521, and rotor loads of § 27.547(d) and (e). The ski and water loads pertain to optional features. Consideration is also required of --

(1) Auxiliary rotor thrust;

(2) The torque reaction of each rotor drive system; and

(3) Balancing air and inertia loads.

b. Procedures. Compliance with this standard is accomplished by application of the specified aircraft loads including engine torque to the fuselage and rotor pylon structure by stress analyses and/or static tests. Drive system torque factors to be used are noted in § 27.547(e) for the main rotor structure.

SUBPART C - STRENGTH REQUIREMENTS

EMERGENCY LANDING CONDITIONS

AC 27.561 EMERGENCY LANDING CONDITIONS--GENERAL.

a. Explanation.

(1) Occupant protection. The occupants should be protected as prescribed from serious injury during an emergency/minor crash landing on water or land for the conditions prescribed in the standard. The standard states that each occupant should be given every reasonable chance of escaping serious injury in a minor crash landing. In addition, the occupants shall be protected from items of mass inside the cabin as well as outside the cabin. For example, a cabin fire extinguisher must be restrained for the load factors prescribed in this section (reference § 27.1411(b)(2).) A transmission or engine must be restrained to the load factors in § 27.561(b)(3) if located above or behind the occupants.

(2) Load factor determination. The standard in § 27.561(b)(3) specifies certain ultimate inertia load factors but allows a lesser downward vertical load factor by virtue of a 5 FPS ultimate rate of descent.

(3) Retractable landing gear. For rotorcraft equipped with retractable landing gear only the retracted configuration must be considered.

(4) Door and exit protection. The minor crash conditions contained in § 27.561(b)(3) should also be considered in designing doors and exits (§ 27.807(b)(4)).

(5) External load considerations. The load factors of § 27.561 and the criteria of § 27.562 are not directly applicable to external load systems. This is because in emergency crash scenarios that involve external loads, the external load is neither typically subjected to the same minor crash loads (§ 27.561) as is the rotorcraft hull and its internal occupants nor are all of the occupant protection criteria (§ 27.562) needed or practicable to apply. Appropriate safety for external load carriage systems is provided by the criteria of § 27.865. Safety standards for external load attaching means are provided in § 27.865.

b. Procedures.

(1) The design criteria report or another similar report of the rotorcraft structural limits should contain the (ultimate) minor crash condition load factors.

(2) Section 27.785 (paragraph AC 27.785) concerns application of this design standard to seats, berths, belts, and harnesses.

(3) The ultimate design landing and maneuvering load factors may exceed the minor crash condition load factors. The highest load factor derived shall be used.

(i) For example, for light weight conditions, the ultimate maneuvering load factor may be 5.25g as specified in § 27.337.

(ii) The ultimate vertical landing load factors derived from §§ 27.471 through 27.521, whichever is appropriate for the design, may exceed the 4.0g down load factor in this section. The rotorcraft landing case design limit contact velocity shall range from 6.5 to 8.3 FPS (see §§ 27.473 and 27.725).

(4) As specified in (b)(3)(iv) of the standard, the downward load factor is 4.0 or a lower design load factor may be used.

(i) The lower load factor relates to a rotorcraft impacting a flat, hard landing surface at 5 FPS (ultimate) vertical rate of descent. The load factor derived for each unique design is a function of the aircraft impact/crushing characteristics.

(ii) The 4.0g down load factor case is related to either a fixed or retractable gear rotorcraft. This condition is not dependent on impact characteristics of the rotorcraft.

(iii) As noted in paragraph b(3) above, the design landing load factors may exceed each of the two previous cases and would then become the prominent design (vertical load) parameter for seats, transmissions, fire extinguishers, etc.

(5) Items of mass such as fire extinguishers, nav-com equipment, life rafts, engines, and/or transmissions shall be restrained for the appropriate load factors.

(6) Cargo/baggage compartments separated from the passenger compartment shall be designed for load factors specified in § 27.787. The conditions in § 27.561 are excepted from that standard.

AC 27.561A. § 27.561 (Amendment 27-25) EMERGENCY LANDING CONDITIONS -GENERAL.

a. Explanation. Amendment 27-25 adds or increases the design static load factor of § 27.561 in two areas. The addition of these load factors eliminates the 5 FPS ultimate descent velocity criteria of unamended § 27.561(b)(3).

(1) The design static load factors for the cabin in § 27.561(b)(3) are increased in concert with the dynamic test requirements of new § 27.562.

(2) Design static load factors are added in § 27.561(c) for external items of mass located above and/or behind the crew and passenger compartment.

b. Procedures. The procedures of paragraph AC 27.561 continue to apply except the new load factors of § 27.561 should be used. Penetration of any items of mass into the cabin or occupied areas should be prevented.

AC 27.561B. § 27.561 (Amendment 27-30) EMERGENCY LANDING CONDITIONS - GENERAL.

a. Explanation.

(1) Amendment 27-30 adds paragraph (d) which lists specific load factors for the fuselage structure in the area of internal fuel tanks located below the passenger floor level. For other locations, the fuselage structure is to be designed to resist crash impact loads prescribed in § 27.561(b)(3) for fuel tanks located within the cabin area; or § 27.561(c) for fuel tanks located behind or above the occupant area. These load factors are provided to prevent crash induced fuel tank ballistic hazards to occupants and to also protect the fuel tank from rupture as prescribed. The landing gear must be retracted if the rotorcraft is equipped with retractable gear.

(2) Section 27.952(b) provides specific load factors for the fuel tanks which are identical to the load factors stated in § 27.561. Paragraph AC 27.952 provides information and guidance for § 27.952 and may be used in conjunction with this paragraph.

b. Procedures. The procedures of paragraphs AC 27.561 and AC 27.561A continue to apply except new load factors are established for fuel tanks located below the passenger floor level. Each fuel tank and its installation are subject to the loads stated in the standard. The load factors are determined by the fuel tank location.

(1) The crash impact load factors for the airframe structure surrounding the underfloor fuel tanks are specified in § 27.561(d). The fuselage structure must be designed to resist the specified crash impact loads and to help protect the fuel tank from rupture. If equipped with retractable landing gear, the effects of the landing gear on fuel system rupture should be considered in both the retracted and unretracted configurations for fuel cell hazard purposes, only, in accordance with AC 27.952.

(2) Section 27.952(b) (see AC 27.952) specifies the design load factors for crash resistant fuel systems in an otherwise survivable impact. This section relates to § 27.561(d) as follows. The § 27.952 load factors are for the fuel tanks, other significant mass items in the fuel system, and their attachment to the rotorcraft airframe for both occupant survivability and retention of fuel in a survivable impact; whereas, the § 27.561(d) load factors only apply to the rotorcraft airframe surrounding the underfloor fuel tanks and their installation for the same reasons. These two sets of load factors are not additive. They are applied separately (as design ultimate load factors) to the portions of the rotorcraft to which they are specified to apply. The application of the § 27.561(d) load factors is described as follows. The loads generated by § 27.561(d) are intended to be applied to the airframe structure surrounding the fuel cell to ensure

that the entire airframe structure provides the appropriate level of crash resistance (i.e., stiffness, crushability, crushing rate, energy absorption capability, etc.) and to ensure that the airframe structure's failure modes (e.g., buckling, creation of sharp edges, structural spears, etc.) are such that fuel cell rupture (and the resultant post crash fire potential) is mitigated to the maximum practicable extent in a otherwise survivable emergency landing. Each fuel cell (and major fuel cell component) creates an applied load on the airframe in an emergency landing condition. These loads are determined by multiplying the worst case mass of the fuel cell (i.e., a full fuel cell) by the load factors of § 27.561(d). These loads are then applied (utilizing the appropriate design load paths) to the airframe structure surrounding the fuel cell to help design the structure for optimal crash resistance. Added stiffness effects for both a full and less than full fuel cell should be considered in the design process. A significantly less than full fuel cell will typically not have any significant stiffness effects, since in a less than full condition the fuel cell cannot typically transfer load hydraulically.

AC 27.561C. <u>§ 27.561 (Amendment 27-32) EMERGENCY LANDING CONDITIONS - GENERAL</u>.

a. <u>Explanation</u>. Amendment 27-32 adds a new rearward emergency load factor of 1.5g to both §§ 27.561(b)(3)(v) and 27.561(c)(5). The addition of the 1.5g rearward load factor in § 27.561(b)(3)(v) is to provide an aft ultimate load condition for substantiation of the restraints required for retention of both occupants and significant items of mass inside the cabin that could otherwise come loose and cause injuries in an emergency landing. The addition of the 1.5g rearward load factor to § 27.561(c)(5) is to provide an aft ultimate load condition for substantiation of the support structure for retention of significant items of mass above and forward of the occupied volume(s) of the rotorcraft that could otherwise come loose and injure an occupant in an emergency landing. Amendment 27-32 also increases the forward, sideward, and downward emergency load factors of § 27.561(c)(2), (c)(3), and (c)(4), respectively; for retention of items of mass above and behind the occupied volume(s) that could otherwise come loose and injure an occupant in an emergency landing.

b. <u>Procedures</u>. The procedures of paragraphs AC 27.561, AC 27.561A, and AC 27.561B continue to apply except the newly specified load factors must be used. A list of the significant items of mass to be considered should be compiled by the applicant and approved by the certifying authority.

AC 27.562. <u>§ 27.562 (Amendment 27-25) EMERGENCY LANDING DYNAMIC CONDITIONS</u>.

a. <u>Explanation</u>. Amendment 27-25 adds new requirements for the dynamic testing of all seats in rotorcraft.

b. <u>Procedures</u>. AC 20-137, "Dynamic Evaluation of Seat Restraint Systems and Occupant Restraint for Rotorcraft (Normal and Transport)," provides procedures for complying with § 27. 562 using the 170-pound anthropomorphic test dummy specified in

§ 27.562(b). Those seats not occupied for takeoff and landing, and so placarded and identified in the rotorcraft flight manual (RFM), may be excluded from compliance.

AC 27.563 § 27.563 (Amendment 27-11) STRUCTURAL DITCHING PROVISIONS.

a. Explanation. Amendment 27-11 included certification requirements for ditching approvals. The rotorcraft must be able to sustain an emergency landing in water as prescribed by § 27.801(e).

b. Procedures. Refer to paragraph AC 27.801 for procedures.

AC 27.563A § 27.563(Amendment 27-26) STRUCTURAL DITCHING PROVISIONS.

a. Explanation. Amendment 27-26 added specific structural conditions to be considered to support the overall ditching requirements of § 27.801. These conditions are to be applied to rotorcraft for which over-water operations and associated ditching approvals are requested.

(1) The forward speed landing conditions are specified as:

(i) The rotorcraft should contact the most critical wave for probable water conditions, in the likely pitch, roll, and yaw attitudes.

(ii) The forward velocity relative to wave surface should be in a range of 0 to 30 knots with a vertical descent rate of not less than 5 FPS relative to the mean water surface.

NOTE: A forward velocity of less than 30 knots may be used for multiengine rotorcraft if it can be demonstrated that the forward velocity selected would not be exceeded in a normal one-engine-out touchdown.

(iii) Rotor lift of not more than two-thirds of the design maximum weight may be used to act through the CG throughout the landing impact.

(2) For floats fixed or deployed before water contact, the auxiliary or emergency float conditions are specified in § 27.563(b)(1). Loads for a fully immersed float should be applied (unless it is shown that full immersion is unlikely). If full immersion is unlikely, loads resulting from restoring moments are specified for sidewind and unsymmetrical rotorcraft landing.

(3) Floats deployed after water contact are normally considered fully immersed during and after full inflation. An exception would be when the inflation interval is long enough that full immersion of the inflated floats does not occur; e.g., deceleration of the rotorcraft during water impact and natural buoyancy of the hull prevent full immersion loads on the fully inflated floats.

b. <u>Procedures</u>.

(1) The rotorcraft support structure, structure-float attachments, and floats should be substantiated for rational limit and ultimate ditching loads.

(2) The most severe wave heights for which approval is desired are to be considered. A minimum of Sea State 4 condition wave heights should be considered (reference paragraph AC 27.801 (§ 27.801) for a description of Sea State 4 conditions).

(3) The landing structural design consideration should be based on water impact with a rotor lift of not more than two-thirds of the maximum design weight acting through the center of gravity under the following conditions:

(i) Forward velocities of 0 to 30 knots (or a reduced maximum forward velocity if it can be demonstrated that a lower maximum velocity would not be exceeded in a normal one-engine-out landing).

(ii) The rotorcraft pitch attitude that would reasonably be expected to occur in service. Autorotation flight tests or one-engine-inoperative flight tests, as applicable, should be used to confirm the attitude selected. This information should be included in the Type Inspection Report.

(iii) Likely roll and yaw attitudes.

(iv) Vertical descent velocity of 5 FPS or greater.

(4) Landing load factors and water load distribution may be determined by water drop tests or analysis based on tests.

(5) Auxiliary or emergency float loads should be determined by full immersion or the use of restoring moments required to react upsetting moments caused by sidewind, asymmetrical rotorcraft landing, water wave action, rotorcraft inertia, and probable structure damage and punctures considered under § 27.801. Auxiliary or emergency float loads may be determined by tests or analysis based on tests.

(6) Floats deployed after initial water contact are required to be substantiated by tests or analysis for the specified immersion loads (same as for (5) above and for the specified combined vertical and drag loads).

SUBPART C - STRENGTH REQUIREMENTS

FATIGUE EVALUATION

AC 27.571. § 27.571 (Amendment 27-26) FATIGUE EVALUATION OF FLIGHT STRUCTURE.

a. Explanation. An evaluation is required to assure structural reliability of the rotorcraft in flight.

(1) Advisory Circular 20-95 contains background information and acceptable means of compliance with the requirements. A safe life may be assigned or the structure may be fail safe as prescribed or a combination of these may be used.

(2) Mandatory inspections, service life (replacement times) etc., determined in complying with the standard shall be placed in the Airworthiness Limitations Section of the Instructions for Continued Airworthiness (also called Maintenance Manual). See Appendix A of FAR Part 27, paragraphs A27.4 and paragraph AC 27.1529 for information.

(3) Amendment 27-26 amended the standard to require evaluation of the landing gear and their related primary attachments.

(4) Amendment 27-26 also amended the standard to require evaluation of ground-air-ground cycles on the rotorcraft, and if applicable, of external cargo operations. Previously external cargo operations were evaluated whenever the rotorcraft cargo combination exceeded the “standard” maximum certificated gross weight, and the CG range specified in § 27.25(c). If these limits were not exceeded, an evaluation was not required by the standard prior to Amendment 27-26.

b. Procedures.

(1) The fatigue evaluation requires consideration of the following factors:

a(i) Identification of the structure/components to be considered.

(ii) The stress during operating conditions.

(iii) The operating spectrum or frequency of occurrence including frequency of ground-air-ground cycles, as well as external cargo operations.

(iv) Fatigue strength, and/or fatigue crack propagation characteristics, residual strength of the cracked structure.

(2) Since the design limits, e.g., rotor RPM (maximum and minimum), airspeed, and blade angles (thrust, weight, etc.) affect the fatigue life of the rotor system, it is necessary that flight conditions be conducted at limits that are appropriate for the particular rotorcraft and at the correct combination of these limits. It will be the responsibility of engineering and flight test personnel to determine that the flight strain program proposal includes conditions of flight at the various combinations of rotor RPM, airspeed, thrust, etc., that will be representative of the limits used in service. The flight test personnel should assure that the severity of the maneuvers to be investigated is such that actual service use will not be more severe. Verification that proposed maneuvers are suitable may be achieved by:

(i) Flying a representative set of maneuvers with the applicant's pilot in the test aircraft at noncritical combinations of weight, CG, and speed. (An FAA/AUTHORITY letter for specific test authorization would ordinarily be required.) If the procedure is used, the applicant should provide adequate preliminary flight strain data from development or other tests to confirm a cleared (non-critical) flight envelope for conduct of these representative maneuvers.

(ii) Flying a representative set of maneuvers with the applicant's pilot in a similar (certified) model to assess and agree upon the required maneuvers, control deflections, and aircraft rates. The required maneuvers or conditions will be specified in the flight strain program plan.

(iii) Flying a chase aircraft which has a flight envelope appropriate to allow visual confirmation of the proposed and programmed flight maneuvers.

(iv) Observation of telemetered flight data to assure desired control deflections, rates, and aircraft attitudes.

(v) Some combinations of items b(2)(i) through b(2)(iv) above.

(3) Assessing the operation spectrum and the flight loads or strain measurement program will involve airframe, propulsion, and flight test personnel.

(4) Variation in the operating or loading spectrum among models, and variations in the spectrum for a particular model rotorcraft, should be evaluated. AC 20-95, paragraph 7, entitled "Loading Spectrum," contains the statement that Table 1 (of the circular) contains typical percent of occurrences for various flight conditions for a single-piston-engine powered small rotorcraft used in utility operations. In addition, the table should be used only as a guide and should be modified as necessary for each particular rotorcraft design.

(5) The difference in loading spectrum for different models that may be anticipated is illustrated by comparing the percentage of time assigned to level flight conditions, specifically 0.8 V_H to 1.0 V_H for three different rotorcraft designs as shown in figure AC 27.571-1. (V_H is the maximum airspeed at maximum continuous power in

level flight.) The first column was obtained from Table 1, AC 20-95 which applies to a single-piston-engine powered small rotorcraft used in utility operations. The second column is appropriate for a single-turbine-engine powered seven-place small business and utility rotorcraft. The third column is appropriate for a twin-engine-powered 13 passenger transport rotorcraft. It should be noted that the level flight percentage of occurrences shown in figure AC 27.571-1 for the turbine utility business and turbine transport rotorcraft are examples of particular designs. The high percentage of time shown in this level flight regime could be unconservative for some designs, especially if the stresses under these design conditions produce an infinite fatigue life for the particular component. The fatigue spectrum percentage of occurrences in AC 20-95 shall be modified according to the intended operational usage of the rotorcraft. However, a conservative application should be considered. This variation illustrates the "tailoring" of the loading spectrum for the type of rotorcraft and the anticipated usage.

FIGURE AC 27.571-1

Comparison Percent of Time in Level Flight

Piston Utility		Turbine Utility Business		Twin Turbine Transport	
0.8 V_{NE}	25%	0.8 V_H	16%	0.8 V_H	15%
1.0 V_H	15%	0.9 V_H	21%	0.9 V_H	20%
1.0 V_{NE}	3%	1.0 V_H	24%	1.0 V_H	38%
Total	43%		61%		73%

(6) External cargo operations are a unique and demanding operation. A "logging" operator may use 50 maximum power applications per flight hour to move logs from a cutting site to a hauling site. Power is used to accelerate, decelerate, or hover prior to load release. Lifting loads over an obstruction or natural barrier is another example of very frequent high power applications for takeoff and for hovering over the release area. Similar types of operations require flight loads data to assess the effects on fatigue critical components.

(7) The impact of the external cargo operation on standard configuration limits should be assessed to determine whether or not the component service lives, inspections, etc., will be affected. The assessment may be done by calculating an "external cargo configuration" service life for each critical component. The lowest service life obtained from standard configuration flight loads data and loading spectrum, or from external cargo configuration flight loads data and loading spectrum or from frequent ground-air-ground cycles is generally the approved service life or replacement time. Since the regulatory maintenance and operating rules do not require recording

time in service for the different types of operations, this procedure could be used if an "operational cycles" equation for equivalent flight hours is not approved (see (8) below).

(8) The Airworthiness Limitations Section of the maintenance manual shall contain the required information derived from complying with the standard. If an "operational cycles" equation for "equivalent flight hours" is approved under the standard, the equation is included in this approved section of the manual.

(9) The applicant should plan to conduct a flight loads survey program for both a standard configuration and an external cargo configuration, if applicable. The ground-air-ground cycle is inherent in these conditions. This procedure will avoid delays associated with reinstallation and calibration of equipment.

AC 27.571A. §27.571 (Amendment 27-33) FATIGUE EVALUATION OF FLIGHT STRUCTURE FOR CATEGORY A CERTIFICATION.

a. Explanation. Amendment 27-33 added Appendix C to specify the requirements for Category A certification of normal category rotorcraft. The requirement for fatigue tolerance evaluation will require test evidence to support the analysis.

b. Procedures. For Category A certification, the tests specified in paragraph AC 29.571A are required for fatigue tolerance evaluation. Paragraph AC 29.571A is repeated in this section.

(1) Fatigue test evidence is necessary for the fatigue evaluation of gears. The test evidence should be provided by rotating tests of complete gearbox specimens operating under power. The tests provide the basis for analysis leading to the establishment of safe life.

(2) The tests are conducted specifically for the purpose of gear tooth evaluation, and components subjected to the tests do not have to be considered serviceable on completion of the test. Excessive wear on bearings and shafts and marking (including spalling) of bearings and gear teeth are acceptable provided no fatigue damage is evident on the gear teeth. However fatigue damage other than tooth fatigue should be considered for test validity and the integrity of the affected part confirmed as necessary.

(3) The test conditions (torque versus number of cycles) should permit the setting of mean strength curve(s) to be associated with each primary gear in the drive train. The test conditions, should at a minimum, encompass those power levels for which repeated application inservice is expected under normal circumstances. The S-N curve(s), for the material and type of gear, should be reduced by a factor of safety to take into account material and manufacturing variability. The factored curve will then be used in conjunction with the flight power spectrum to determine a life (limited or unlimited) for the gears in the primary drive system.

(4) Special procedures, which do not affect fatigue evaluation of the gear teeth, may be allowed to facilitate completion of the test provided they have been justified and they do not affect life determination. These include periodic interruption for inspection, etc., replacement of non-critical parts and the use of special lubricants, special cooling systems, and methods to prevent unrepresentative deflections at the test torque levels.

(5) From evidence in relation to the strength of steel gears of conventional design, it is accepted that adequate fatigue strength can be demonstrated by the use of the above safety factor of 1.4 for a single test, 1.35 for two tests, 1.32 for three tests, and 1.3 for four or more tests. Where several tests are to be conducted, specimens should be selected from different manufacturing batches if practicable.

(6) The demonstration of infinite life for gear teeth will normally require tests of a minimum of 10^7 cycles duration at factored power levels. Use of shorter duration tests should be justified.